



---

**Review Article**

# Short Sleep Duration and Circadian Rhythms: Association with Suicidal Behaviour

Tânia Isabel Santos Pereira<sup>1,\*</sup>, Sónia Patrícia Vilar Martins<sup>1,2</sup>,  
Lia Paula Nogueira Sousa Fernandes<sup>1,2,3</sup>

<sup>1</sup>Faculty of Medicine, University of Porto, Porto, Portugal

<sup>2</sup>Center for Health Technology and Services Research/CINTESIS, University of Porto, Porto, Portugal

<sup>3</sup>Clinic of Psychiatry and Mental Health, São João Hospital Center, Porto, Portugal

**Email address:**

mimed11219@webmail.med.up.pt (T. I. S. Pereira)

\*Corresponding author

**To cite this article:**

Tânia Isabel Santos Pereira, Sónia Patrícia Vilar Martins, Lia Paula Nogueira Sousa Fernandes. Short Sleep Duration and Circadian Rhythms: Association with Suicidal Behaviour. *International Journal of Psychological and Brain Sciences*. Vol. 2, No. 2, 2017, pp. 46-62.

doi: 10.11648/j.ijpbs.20170202.13

**Received:** March 7, 2017; **Accepted:** March 18, 2017; **Published:** April 13, 2017

---

**Abstract:** The current lifestyles in modern societies promote a behaviourally-induced sleep deprivation and circadian rhythm alterations. Some sleep disorders influence the development of suicidal behaviours. This study aims to review the literature exploring the association of both short sleep duration and sleep circadian rhythms with suicidal behaviours. A review was conducted in the PubMed database, using the query (“circadian rhythms” OR “sleep” OR “sleep disorders”) AND (“suicide” OR “suicidal behaviour” OR “suicidality”). The results were filtered for the last 10 years, with 522 results. Studies relating sleep disorders or circadian rhythms with suicidal behaviours, using a well-defined index for sleep disorders, and any measure of suicidal behaviour, were included. After the selection criteria, 48 studies were selected for qualitative analysis. An association between short sleep duration and an increased risk of suicidal behaviour was found in most of the studies with children/adolescents and adults. Particularly, studies measuring weekend vs. weekday sleep duration suggest a concrete role of behaviourally-induced sleep deprivation in this increased risk. Contrastingly, in studies with the elderly, that association was not significant. For sleep circadian rhythms, the studies point to an association between an evening-type chronotype and suicidal behaviours. The results suggest a significant association of short sleep duration and evening-type chronotype with suicidal behaviours, for youth and adults. Both sleep disorders could be connected through a behaviourally-induced sleep deprivation. These associations can provide possible fields of intervention to prevent suicide.

**Keywords:** Sleep Deprivation, Circadian Rhythm, Suicide, Suicidal Ideation, Suicide Attempts

---

## 1. Introduction

Suicide is a complex behaviour and a serious public health problem, affecting all ages and socioeconomic groups, with severe implications to families and society [1-3]. The last records of the World Health Organization [4] report that suicide is responsible for more than 800 000 deaths per year worldwide, and the number of attempted but unsuccessful suicides clearly outdoes this [5]. About 86% of deaths by suicide occur in individuals under 70 years of age. Suicide incidence begins to increase rapidly during adolescence, being

the second leading cause of death among 15-29 year-olds [4]. Death thoughts and wishes to die are the first steps of a process that can proceed to suicidal ideation, suicide attempts or even death by suicide. These are all generally known as suicidal behaviours [6].

The fact that suicide comprises a preventable cause of death raises the importance of identifying risk factors that can be controlled [5]. Many risk factors have been associated with suicide [7-10], such as psychiatric disorders (depression being probably the most important risk factor [1]), impulsive or aggressive behaviour, family history of suicide, loss of a close friend or relative, physical or sexual abuse, lack of a support

network, or sleep disturbances, especially with a chronic evolution [1, 11]. Concerning this last factor, nightmares and insomnia have been consistently reported to increase the risk of suicidal behaviours, even after adjusting for depression severity (e.g. [12, 13]).

In fact, sleep could actually influence mental health and the emergence of suicidal behaviours, since countries with the highest suicide rates, such as Japan and South Korea, are also the most “sleep deprived” countries [1, 14]. This is thought to be related to cultural factors, more than biological features: people in these countries suffer more pressure to succeed at school and work, with more hours of labour, frequently falling into a state of chronic sleep deprivation [1]. Additionally, insomnia and suicidal behaviours seem to share some neurobiological pathways, including serotonergic dysregulation, alterations in the hypothalamic-pituitary-adrenal (HPA) axis, elevations in proinflammatory cytokines, and alterations in brain structure, namely in the prefrontal cortex [15, 16].

Sleep is a key process in human life, having a regulatory role on several organic and cognitive functions [17-19]. Moreover, sleep is also an important determinant of a person's general well-being. It has been described as a daily process of restoration and recovery of the human body in general, and of synaptic homeostasis in particular [16, 17, 20], contributing to emotional regulation, cognition, attention, adequate psychosocial and physical development, and proper functioning of physiological systems, such as the immune and endocrine systems [2, 14, 17, 21].

Sleep, as other physiological functions, is determined by circadian rhythms [22]. Melatonin levels vary during a 24 hours cycle, leading individuals to generally feel sleepier in the evening and more alert in the morning [23]. Variations in the circadian rhythms among individuals, either natural or behaviourally-induced, allow the classification of their chronotype as morning-type (preference for activities in the morning), evening-type (performing more activities in the evening), or intermediate chronotype [22, 24]. Individuals showing different chronotypes have demonstrated differences in their sleep-wake patterns and in their biological and behavioural rhythms [24].

It is important to note that the current lifestyle in modern societies exerts increasing pressure for individuals to work more hours, and results in different spare time activities. Most individuals spend more time at home using digital media, mainly at night, after they come home from work or school. These factors tend to affect sleep in two ways: on one hand, a greater tendency for activities late in the evening may lead to an alteration in the circadian rhythms (sleep-wake cycle), with individuals going to sleep later and feeling the need to wake up later in the morning; on the other hand, sleep duration tends to be restricted, as individuals still have to wake up early in the morning due to work or school schedules. This results in a behaviourally-induced sleep deprivation, that is independent from sleep pathologies or psychiatric disorders – whenever it is possible, the individual sleeps a normal number of hours without any sleep disturbance [20].

A long weekend catch-up sleep duration indicates that the individual is sleeping less than he/she needs during weekdays. Most likely, this occurs due to a behaviourally-induced sleep deprivation. Taking this into account, it has been suggested that weekend catch-up sleep duration is a better indicator of chronic sleep deprivation than is the simple measurement of sleep duration on weekdays, since the first is not influenced by pathologies that could affect sleep duration or by the natural tendency of the individual for being a short sleeper [14, 20].

With the emergence of this behaviourally-induced sleep restriction and circadian rhythm alteration, it is important to evaluate their consequences on public health, looking for possible interventions to prevent them. Given the influence of sleep disorders over suicide risk [1], it is crucial to determine the role of those altered sleep habits in the development of suicidal behaviours.

Adults are especially susceptible to behaviourally-induced sleep deprivation, but other age groups are also at risk for those consequences. For children and adolescents, it was found that: a) the sleep habits acquired in childhood persist through adulthood and largely influence sleep patterns later in life [11, 16]; b) adolescents have a biological tendency to suffer circadian rhythm alterations characterized by a sleep phase delay, tending to sleep later, but still have to wake up early due to school or family obligations [5, 25-28]. This promotes a circadian desynchrony and a state of sleep deprivation, if good habits about bedtime and activities performed before sleep are not induced at home; c) they also are a risk group for suicide, likely due to a proneness for emotional instability and impulsive behaviours, with a less developed ability to correctly evaluate the long term consequences of their behaviours [14].

On the other extreme, the elderly face a number of changes in their lifestyle, body and behaviour, with health problems and some important losses. The adaptation to these changes is not always easy, possibly increasing the risk for suicidal behaviours [6]. Therefore, it is important to identify some modifiable risk factors, in order to prevent suicide in this population. Sleep disturbances and short sleep duration are fairly common in this population [6], so it is important to determine whether these particular factors increase the risk for suicidal behaviour.

The available data on this matter is not consistent, mainly due to methodological issues: experimental studies in this area are hardly considered ethical, and there is a lack of prospective studies, making it difficult to define an association and the direction of causality. The aim of this review is to analyse the literature concerning a possible effect of short sleep duration and of sleep circadian rhythms on the development of suicidal behaviours.

## 2. Methods

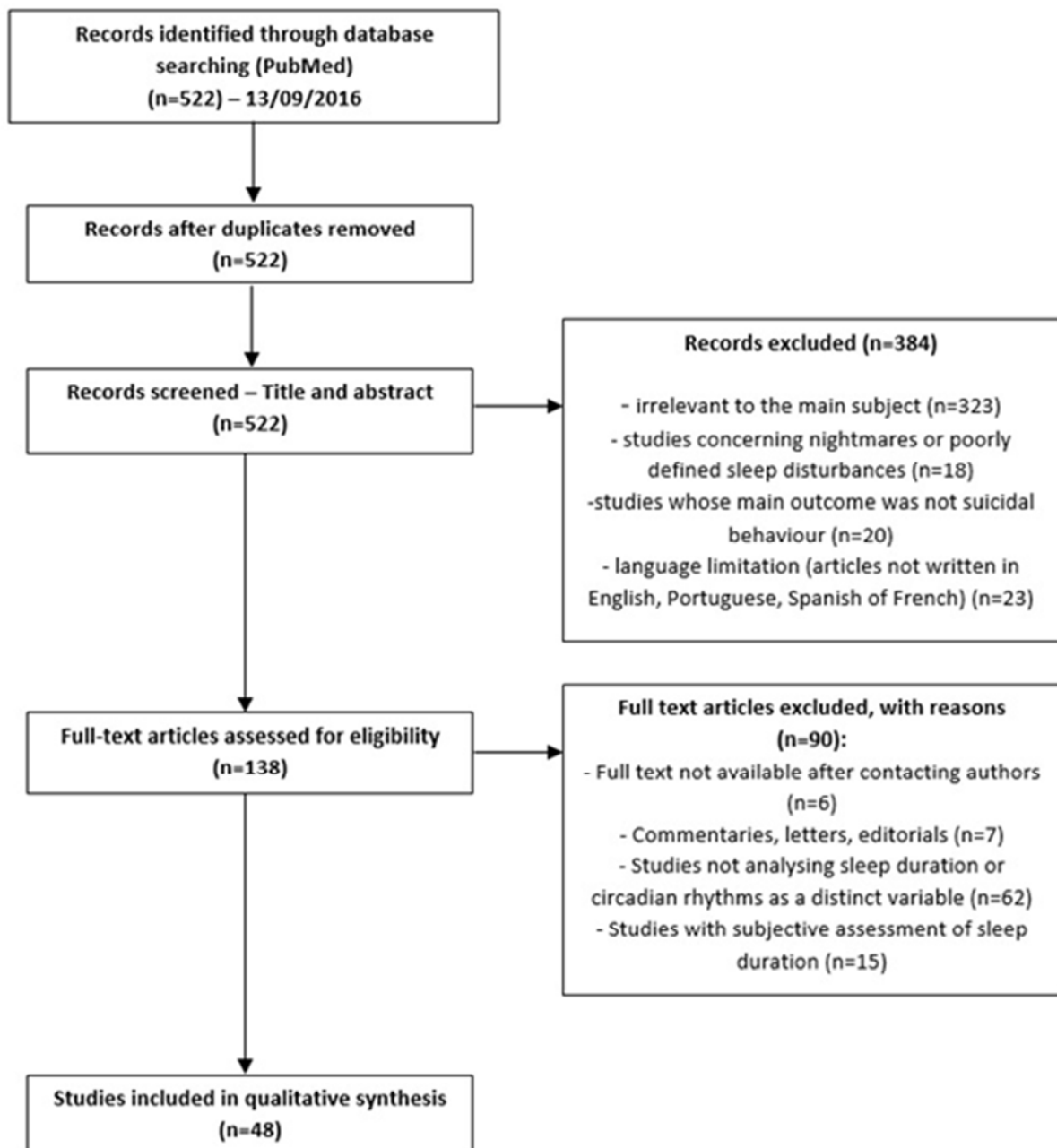
A Web-based literature research was performed at the PubMed database, using the following search query: (“circadian rhythms” OR “sleep” OR “sleep disorders”) AND (“suicide” OR “suicidal behaviour” OR “suicidality”). A

search filter was applied to obtain studies published only in the last 10 years.

A first selection of the obtained results was performed by analysing their title and abstract, following defined inclusion criteria: a) articles concerning the presence or absence of an association between sleep disorders or circadian rhythms and suicidal behaviours, for any demographic characteristics and either for healthy individuals or psychiatric patients; b) studies using a well-defined index for sleep disorders; c) studies having as outcome any measure of suicidal behaviour (including wishes to die, suicidal ideation, suicidal attempts and death by suicide). The following exclusion criteria were applied at this phase: a) articles in languages other than English, Portuguese, Spanish or French; b) articles considered

to be out of the main subject; c) studies concerning only nightmares or poorly defined sleep disturbances; d) studies whose main outcome was not suicidal behaviour (also excluding self-harm behaviour without a suicidal intention). The access to full-text was restricted in some of the articles, in which case the authors were contacted by e-mail.

A second selection, consisting of the analysis of the included articles in full-text, was performed using another set of exclusion criteria: a) full text not available after contacting authors; b) commentaries, letters and editorials; c) studies not analysing sleep duration or sleep circadian rhythms as a distinct variable; d) studies regarding sleep quality or with a subjective assessment of sleep duration.



*Figure 1. Study selection strategy.*

The studies selected for qualitative analysis include articles concerning two major subtopics: a) short sleep duration and suicidal behaviours, and b) sleep circadian rhythms and suicidal behaviours. To analyse the information in those studies, groups were defined according to age stage: children and adolescents (<18 years old), adults (18-65 years old), and elderly (>65 years old). These categories were defined according to the lower values considered in the included studies.

For an easier comparison of the research studies included in this review, tables were created to summarise each study's information, including their authors, country, year, study design, sample size and type, assessment of sleep duration/sleep circadian rhythm alterations, suicidal behaviours considered as outcome, and a summary of the main findings.

### 3. Results

The literature research generated  $n=522$  results by September 13<sup>th</sup> 2016. Figure 1 shows detailed information on the selection criteria, number of articles included and excluded. In a first phase, after applying the inclusion and exclusion criteria, 384 articles were excluded. From the remaining studies, 90 were excluded at the second phase. Finally,  $n=48$  articles were included for qualitative analysis.

Among these studies, 5 were review articles and 43 were research articles. There were 33 studies regarding short sleep duration and 15 concerning circadian rhythm alterations.

#### 3.1. Short Sleep Duration and Suicidal Behaviour

Among the 33 studies concerning this subject, 1 was a review article, 1 was a qualitative study, and another was a case-report. The remaining 30 research articles included 16 studies in adults, 12 in children and adolescents, and 2 in the elderly.

The definition of "short sleep" varied between the studies, ranging from <4 hours to <8 hours of sleep (e.g. [18, 29-31]). Yet another variable was the number of categories considered for sleep duration, varying from 2 to 7 or even considering sleep duration as a continuous variable.

The outcome measures also varied between studies, considering death thoughts, suicidal ideation, suicide attempts, deaths by suicide, or several combinations of these outcome measures.

Detailed information on these variables and other characteristics of these studies can be found in the tables 1, 2 and 3.

##### 3.1.1. Children and Adolescents

The 12 studies regarding short sleep duration and suicidal behaviours in this age group were mostly cross-sectional studies, with only 1 longitudinal prospective study [32] and 1 case-control study [33]. Among the 12 articles, only 1 [33] did not find any statistically significant association.

Park *et al.* [31], after controlling for several factors, found a significant association with suicidal ideation only, but not with suicide attempts. Fitzgerald *et al.* [5] found a significant

association between a reduced sleep time and suicidal ideation, suicide planning, and suicide attempts, after adjusting for age, gender, race, feelings of sadness, and substance abuse.

Another study worth mentioning was conducted by Winsler and colleagues [28] in a community with very early school times, performing a continuous evaluation of sleep duration. The authors found that just 1 h less of sleep during weekdays was significantly associated with greater odds of serious suicidal ideation and suicide attempts. As the number of hours of sleep increased until 9 hours (considered the adequate sleep duration for adolescents), those odds decreased significantly, in a fairly linear manner. Each hour less of sleep was associated with a 42% increase in the odds of suicidal ideation – 21% when controlling for feelings of hopelessness. Each hour less of sleep per night was also associated to 58% greater odds of attempting suicide – 26% after controlling for hopelessness, and 14% when controlling for both hopelessness and suicidal ideation. However, as the number of hours increased to  $\geq 10$  on weekdays, there was a new slight but significant increase in the report of suicidal ideation and attempts. These authors suggest a U-shaped association between sleep duration and suicidal behaviours, with a nadir close to the recommended value of 9 hours of sleep per night.

Two of the studies focused on the differences between weekday sleep duration vs. weekend sleep duration, an indicator of chronic, behaviourally-induced sleep deprivation on weekdays [14, 20]. Kang *et al.* [14], found that only weekend catch-up sleep duration, and not short sleep on weekdays, predicted a greater risk for suicidal ideation. In the study conducted by Lee and colleagues [20], after controlling for insomnia, sleepiness and snoring, short weekday sleep duration was no longer associated to suicidal ideation, but a longer weekend oversleep and larger weekend rise time delay still were. Thus, a large difference between sleep duration on weekdays and on weekends predicted higher suicidality. The authors concluded that a chronic, behaviourally-induced sleep deprivation may increase the risk of suicide in adolescents.

It is noteworthy that An *et al.* [29] found not only an association between insufficient sleep and suicidal ideation, but also that psychosocial/environmental factors in general (e.g. sufficient sleep, satisfaction with family, satisfaction with one's health) had a 2-fold greater influence on adolescent suicidal ideation than did genetic factors. In accordance, Matamura *et al.* [32], studying sleep duration and bedtimes in monozygotic twins, found that the association between sleep habits and mental health was not explained by genetic factors or by other shared environmental factors.

##### 3.1.2. Adults

Most of the 16 quantitative research studies conducted in adults were cross-sectional, with 2 retrospective [34, 35], 1 prospective [21] and 1 case-control studies [18].

Among the 16 studies, 5 of them did not find any statistically significant association between short sleep duration and suicidality [34, 36-39].

According to Luxton *et al.* [40], individuals with very short

sleep duration (<6 hours) had an increased risk for all health-risk behaviours, including suicidal ideation or suicide attempts, when compared to those with either short (<7 hours) or normal ( $\geq 7$  hours) sleep duration, suggesting that the risk increment is larger with a more severe sleep deprivation.

Bae et al. [41] considered shorter and longer than normal sleep duration in the same category, named “abnormal sleep duration” ( $\leq 5$  or  $\geq 10$  hours of sleep). In a linear regression analysis, suicidal ideation was significantly related to abnormal sleep duration, although after controlling for age and gender the correlation was not significant.

Many other studies obtained significant relationships even after controlling for various factors, such as sedative/hypnotic medication [21], chronic diseases [17], physical activity [42], panic, mood or substance use disorders [43], and depression [7].

Lee et al. [17] found an association between short sleep duration (<6 hours) and suicidal thoughts, which only remained significant for men, after controlling for sociodemographic factors and chronic diseases.

Blasco-Fontecilla et al. [18] compared the prevalence of short sleep between suicide attempters, psychiatric patients (controls), and healthy controls. Short sleep ( $\leq 5$  hours) was significantly more prevalent in suicide attempters than in psychiatric patients, but only for males. When comparing with healthy controls, the association was significant for both genders. Additionally, an association of short sleep with suicide risk and severity of the attempts was found, but only for females.

In the study conducted by Chin et al. [44], sleep time was significantly associated with suicidal ideation among women, but not among men, when controlling for sociodemographic factors, self-rated health, stress and depression.

Krakow et al. [35] found that individuals with suicidal ideation had a lower sleep efficiency (proportion of the time in bed spent asleep), but the association disappeared when controlling for depression. Ferentinos et al. [15], on the other hand, constructed a model according to which the effect of age, major depression, affective disorder and substance-use disorders on suicidal intentions was mediated by short sleep time. Also Gelaye and colleagues [7], in a study with pregnant women, found that participants with suicidal ideation were more likely to report short sleep duration, even after adjusting for maternal depression.

### 3.1.3. Elderly Population

The 2 studies regarding short sleep duration in older adults were cross-sectional. In both of them, no significant association of sleep duration with suicidal behaviours was found, although there was a non-significant trend towards a higher risk of suicidal feelings [6, 45].

## 3.2. Sleep Circadian Rhythms and Suicidal Behaviour

A total number of 15 studies concerning this subject was selected, among which 4 were reviews. Of the 11 research articles, 6 were conducted with adult individuals, and 5 regarded children and adolescents. No studies were found in

the elderly population.

Detailed information on the characteristics of these studies can be found in the tables 4 and 5.

### 3.2.1. Children and Adolescents

Among the 5 studies concerning this age group, 1 was a prospective study [46] and the remaining 4 were cross-sectional [2, 22, 25, 26]. All 5 studies pointed to a significant effect of an evening-type chronotype, or circadian reversal specifically [25], on suicidal behaviours. However, Kim et al. [2] obtained this result for suicide attempts only; for suicidal ideation and suicide plans, the risk increased with early bedtimes. These authors suggest a U-shaped association of awakening time and bedtime with suicidal behaviours.

Gau et al. [22] found that adolescents with an evening-type chronotype were more likely to have suicidal thoughts or attempts. The magnitude of the association decreased but remained significant after controlling for the tendency for internalizing or externalizing problems.

The study conducted by McGlinchey and Harvey [46] is worth mentioning because it involves both a cross sectional analysis and a prospective analysis through the years, with follow-up until early adulthood. They found that late bedtimes were associated with risk behaviours and negative health outcomes, including suicidal ideation and attempts, both cross-sectionally and longitudinally. They also suggest a dose effect: the later the bedtime in adolescence, the greater the risk for suicidal behaviours in adulthood. Another study by McGlinchey et al. [25] later indicated circadian reversal as a significant predictor of suicide attempts.

In a study by Gangwisch et al. [26], adolescents with parental set bedtimes of midnight or later were 20% more likely to have suicidal ideation (OR: 1.20), when compared to those with parental set bedtimes at 10 PM or earlier, even after controlling for demographic variables, self-perception of parents' care, and depression. The inclusion of sleep duration and perception of getting enough sleep in the analysis attenuated this association (OR=1.09), suggesting that these variables could act as mediators.

### 3.2.2. Adults

Among the 6 studies in adults, 3 of them performed a cross-sectional analysis of chronotype and the presence of suicidal behaviours [47-49], 2 were case-control studies [10, 24], and 1 was a retrospective study [3]. In 4 of these studies, a significant increase in suicide risk was found for the evening-type chronotype [3, 47-49].

Chan et al. [48] showed that individuals with an evening-type chronotype had higher levels of suicidality. The study conducted by Dell'Osso et al. with post-traumatic stress disorder patients [49] showed an association of sleep rhythmicity dysregulations with suicidal ideation, but not with suicide attempts. The nature of the associations was maintained after adjusting for depression. Perlis et al. [3] concluded that, when taking into account the proportion of population awake at a given hour, the majority of suicides happened at night, peaking at 2:00-2:59 AM.

Benedetti and colleagues [47] present a different sort of

evidence. They analysed the association between the presence of a \*C polymorphism in the rs1801260 gene (a CLOCK gene typically involved in sleep phase delay and insomnia) and suicidality, in patients with bipolar disorder. The rs1801260\*C polymorphism alone did not influence the likelihood of attempting suicide in these patients, but seemed to increase the

effect of early life stressful events in the probability of attempting suicide in adulthood. This gene also seemed to modulate the relation between a positive history of attempted suicide and current suicidality, with a higher effect being evident on the \*C allele carriers.

**Table 1.** Characteristics of the studies concerning short sleep duration and suicidal behaviour in children and adolescents.

| Authors, Year (Country)                  | Study type                              | Sample   | Sleep duration definition  | Suicidal behaviour                    | Main results  |
|--|---|--|--|---------------------------------------|---|
| An, H., et al., 2010 (Korea)             | Cross-sectional                         | N=2965<br>Adolescents + their parents (community)    | SSD: <6h (sufficient sleep: 6-8h)  | SI                                    | SSD was associated with an increased risk for SI (OR: 1.431). Psychosocial factors (e.g. sufficient sleep, satisfaction with one's family, and with one's health) had a 2-fold greater influence on adolescent SI than genetic factors.   |
| McKnight-Eily, L. R., et al., 2011 (USA) | Cross-sectional                         | N=12 154 (community)                                 | Insufficient sleep: <8h Sufficient sleep: ≥8h)   | SI (in the last year)                 | Insufficient sleep on an average night in school time was strongly associated (p=0,00) with higher odds of having seriously considered attempting suicide.  |
| Yen, C.F., et al., 2010 (Taiwan)         | Cross-sectional                         | N=8319 (community)                                   | SSD: < 15 <sup>th</sup> percentile of the population. Average sleep duration: 15 <sup>th</sup> - 85 <sup>th</sup> percentiles. Long sleep duration: > 85 <sup>th</sup> percentile. | SI or SA                              | SSD at night was associated with SI and SA (even after controlling for depression and socio-demographic characteristics – the association was only significant in adolescents without depression. Long sleepers (≥8h) were less likely to report suicidality.   |
| Park, J. H., et al., 2013 (Korea)        | Cross-sectional                         | N=74 698 (community)                                 | Sleep duration in 6 categories: <4h; 4 - <5h; 5 - <6h; 6 - <7h; 7 - <8h; ≥8h   | SI, SA                                | Sleep duration of <4h/night and never feeling refreshed after sleep increased the likelihood of SI, but not of SA, even after controlling for demographic factors, tobacco and alcohol use, and subjective feelings of depression. (OR= 1.43 for ≤4h).  |
| Fitzgerald, C.T., et al., 2011 (USA)     | Cross-sectional (2 independent surveys) | N=12 154 (in 2007)<br>N=14 782 (in 2009) (community) | Sleep duration in 7 categories: ≤4h; 5h; 6h; 7h; 8h; 9h; ≥10h  | SI, SP, SA, or SA requiring treatment | The risk of SB was significantly higher for adolescents sleeping ≤5h (≤6h for SI and SP) or ≥10h (only for SA requiring treatment), when compared to those sleeping 8h (with the lowest risk). The risk seems to increase with both shorter or longer sleep durations. The largest ORs were found for the most severe forms of SB (SA requiring treatment): OR=5.9 for ≤4h and OR=4.7 for ≥10h. The associations were maintained after adjusting for age, gender, race, feelings of sadness, and substance abuse. |
| Lee, Y. J., et al., 2011 (Korea)         | Cross-sectional                         | N=8010 (community)                                   | SSD: ≤7h<br>BISD – sleep duration on weekdays ≤7h, long weekend oversleep ≥2h, severe daytime sleepiness, and absence of significant insomnia.                                     | SI                                    | Subjects with BISD had higher scores for SI, comparing to those sleeping ≥7h (after controlling for age, sex, depression). When the sleepiness score, insomnia and snoring were included, the indicators of BISD were independently associated with a higher SI score. In subjects without BISD, weekend oversleep was not associated to SI.  |

| Authors, Year (Country)   | Study type                     | Sample  | Sleep duration definition   | Suicidal behaviour | Main results   |
|---|--------------------------------|---|---|--------------------|--|
| Kang, S.G., et al., 2014 (Korea)  | Cross-sectional                | N=4145 (community)  | Weekend catch-up sleep duration (excess of sleep on weekends vs. weekdays, typical of BISD) | SI, SA             | Both SI and SA were associated with longer weekend catch-up sleep duration (after multivariate regression analysis), but not with sleep duration on weekdays.  |
| Koyawala, N., et al., 2015 (USA)  | Case-control                   | N= 80 adolescents (+ their parents)<br>Cases: 40 adolescents who had attempted suicide<br>Controls: 40 adolescents without history of SB or self-harm | Bedtime and wake-up time<br>Parents were asked if their child got enough sleep              | SA                 | Sleep duration during either weeknights or weekend nights was not significantly different between the SA and or non-SA groups. Only total sleep scores were higher with SA.  |
| Matamura, M., et al., 2014 (Japan)  | Prospective (3-year follow-up) | N=314 Adolescents (monozygotic twins in the community)  | Sleep duration in hours (as a continuous variable)  | SI                 | Both short sleep duration and late bedtimes were significantly associated with SI, independently from genetic and shared environmental factors. The results were still statistically significant after controlling for bedtime regularity.   |
| Winsler, A., et al., 2015 (USA)   | Cross-sectional                | N=27 939 Adolescents (in a community with very early school start times)  | Sleep duration in hours (as a continuous variable)  | SI, SA             | The lowest odds of reporting hopelessness, SI and SA were seen for 9h of sleep. Each hour less of sleep per night was associated with a 42% increase in the odds of serious SI, still significant when controlling for hopelessness (21% increase). Each hour less of sleep also caused a 58% increase in the odds of SA, still significant after controlling for hopelessness (26%) and for both hopelessness and SI (14%). Thus, the odds of SB decreased continuously and almost linearly, as the sleep time increased until 9h. Even with an adequate sleep duration, having just 1h less of sleep during weekdays significantly increased those odds. For $\geq 10$ h of sleep on weekdays, there was a new slight but significant increase in the report of SI and SA. |
| Sarchiapone, M., et al., 2014 (Austria, Estonia, France, Germany, Hungary, Ireland, Israel, Italy, Romania, Slovenia and Spain) | Cross-sectional                | N= 11 788 (community)   | Sleep duration in hours (as a continuous variable)  | SI                 | Reduced sleep was associated with increased scores of SI, even in a multivariate analysis including all significant variables.   |
| Arnold, E. M., et al., 2013 (USA)   | Cross sectional                | N=80 American Indian Youth (ages 11-18)   | Sleep duration: continuous evaluation of time in bed  | SI                 | More time in bed per night decreased the likelihood of SI (OR=0.617; after multivariate analysis, OR=0.577), while not being associated to depression.   |

SSD: short sleep duration; BISD: behaviourally-induced sleep deprivation; SB: suicidal behaviours; SI: suicidal ideation; SP: suicidal plans; SA: suicide attempts.

**Table 2.** Characteristics of the studies concerning short sleep duration and suicidal behaviour in adults.

| Authors, Year (Country)                              | Study type      | Sample   | Sleep duration                                  | Suicidal behaviour                             | Main results   |
|--|-----------------|--|---|--|--|
| Blasco-Fontecilla, H., et al., 2011 (Spain)          | Case-control    | N=1026. Cases: suicide attempters (n=434)<br>Psychiatric inpatients (controls): (n=83)<br>Healthy controls (n=509) | SSD: $\leq 5$ h                                 | SA (risk and lethality);<br>SI; Suicide risk   | SSD was significantly more prevalent in individuals with SA than in other psychiatric patients, only for males. When comparing with healthy controls, the association was significant for both genders. In females with SA, SSD was significantly associated with SI and high suicide risk.  |
| Goodwin, R. D., et al., 2008 (USA)                   | Cross-sectional | N=8098 (community)   | SSD: $\leq 5$ h                                 | Current (in the past year) SI; Lifetime SI; SA | SSD was associated with significantly increased odds of SI and SA. Current SI was associated with either current or lifetime SA. This third association became non-significant after adjusting for factors such as panic disorder, mood, and substance use disorders, which could mediate this relation.   |
| An, K. O., et al., 2015 (Korea)                      | Cross-sectional | N=4674 (community)   | SSD: $\leq 5$ h                                 | ST   | SSD was significantly and independently associated with a 1.8-fold increase in the risk of ST (after adjusting for confounding factors, like physical activity).   |
| Ferentinos, P., et al., 2016 (Greece)                | Cross-sectional | N=127<br>Suicide attempters  | SSD: $\leq 5$ h<br>(in an average night)        | SI   | SI was predicted by reports of SSD in the two weeks prior to the SA, and by the concomitant presence of insomnia and SSD. The models constructed show significant indirect effects of major depression, affective disorder, and alcohol-related disorder on SI, through a short sleep time. SSD also partially predicted an association between increasing age and SB. |
| Chin, Y. R., Lee, H. Y., and So, E. S., 2011 (Korea) | Cross-sectional | N=6969 (community)   | SSD: $\leq 5$ h<br>NSD: 5-8h<br>LSD: $\geq 8$ h | SI   | Among women, SSD was significantly associated to SI, even after controlling for socio-demographic factors, self-rated health, stress and depression. Among men, the association was no longer significant after adjustment. In multivariate analysis, women who slept 5-8h showed less SI.   |
| Lee, M.S., et al., 2015 (Korea)                      | Cross-sectional | N=17 638 (community)   | SSD: $\leq 6$ h<br>NSD: 7-8h<br>LSD: $\geq 9$ h | ST   | Individuals with ST were more likely to sleep $\leq 6$ h or $\geq 9$ h. After full adjustment for demographic variables and chronic diseases, the association of SSD with ST was maintained for men, but not for women. The association with long sleep duration disappeared after adjustment.   |



| Authors, Year (Country)             | Study type  | Sample  | Sleep duration  | Suicidal behaviour      | Main results  |
|-------------------------------------|---|---|---|-------------------------|---|
| Chakravorty, S., et al., 2014 (USA) | Retrospective chart review                          | n=161<br>Veterans with alcohol abuse disorder                       | SSD: $\leq 6h$<br>NSD: 7-8h<br>LSD: $\geq 9h$                     | SI (over the past year) | Subjects reporting SI had significantly shorter sleep duration, but only in the unadjusted model. Veterans with SSD were more likely to experience all of the five SI symptoms assessed in the previous year, than those with NSD or LSD. In the multivariate analysis, no significant association was found between sleep duration and SI. |
| Luxton, D.D., et al., 2011 (USA)    | Cross-sectional                                     | N=2738<br>Redeployed soldiers                                       | VSSD: $<6h$<br>SSD: $<7h$<br>NSD: $\geq 7h$                       | SI; SA                  | Individuals reporting VSSD were at increased risk for SI or SA, relative to those with either SSD or NSD.   |
| Gunnell, D., et al., 2013 (Taiwan)  | Prospective cohort study (mean follow-up 7.4 years) | N=393 983 (community)   | VSSD: 0-4h<br>SSD: 4-6h<br>NSD: 6-8h<br>LSD: $>8h$                | Death by suicide        | There was a reverse J-shaped association between sleep duration and suicide risk. Hazard ratios by sleep duration: HR=3,5 for 0-4h of sleep, HR=1,5 for 4-6h, and HR=1,5 for $>8h$ . The association with long sleep disappeared when controlling for sedative/hypnotic medication and psychotropic drug use.                               |
| Bae, S.M., et al., 2013 (Korea)     | Cross-sectional                                     | N=1000 (community)  | Abnormal sleep duration: SSD ( $\leq 5h$ ) or LSD ( $\geq 10h$ ). | SI                      | In the linear regression analysis, SI was related to abnormal (short or long) sleep duration; adjusted $r^2=0.275$  |
| Weis, D., et al., 2016 (Israel)     | Cross-sectional                                     | N=460<br>College students (community)                               | Sleep duration as assessed in the PSQI scale                      | SI, SP or SA.           | There was no significant effect of sleep duration on SB.  |
| Wigg, C. M., et al., 2014 (Brazil)  | Cross-sectional                                     | N=98<br>Patients with epilepsy*                                     | Sleep duration as assessed in the PSQI scale                      | SI                      | Sleep duration did not differ between patients with or without SI, although those with SI reported worse sleep quality and more sleep problems.   |
| Gelaye, B., et al., 2015 (Peru)     | Cross-sectional                                     | N=641<br>Pregnant women   | Sleep duration as assessed in the PSQI scale                      | SI                      | Poor sleep was significantly associated to an increase on SI, even after adjustment for maternal depression. In particular, SSD was more commonly reported by women with SI.  |
| Krakow, B., et al., 2011 (USA)      | Retrospective chart review                          | N=1584<br>Patients from a sleep medical center                      | Sleep efficiency (amount of time asleep while being in bed)       | SI                      | Patients with SI had more frequent and more chronic sleep problems in general. Although they spent more time in bed, their sleep efficiency was significantly worse. These last two associations were no longer significant when controlling for depression.  |
| Tang, W.K., et al., 2011 (China)    | Cross-sectional                                     | N=787<br>Patients with acute ischemic stroke (first or recurrent)** | Number of hours asleep per night                                  | SI                      | No significant association was found between sleep duration and SI. Frequent awakenings were the only sleep complaint that significant predicted SI.  |

| Authors, Year (Country)           | Study type      | Sample            | Sleep duration                                 | Suicidal behaviour | Main results  |
|-----------------------------------|-----------------|-------------------|--|--------------------|---|
| Pigeon, W. R., et al., 2015 (USA) | Cross-sectional | N=767 (community) | Total sleep time (assessed with a sleep diary) | SI                 | No significant association was found between total sleep time and SI. |

SSD: short sleep duration; VSSD: very short sleep duration; NSD: normal sleep duration; LSD: long sleep duration; BISD: behaviourally-induced sleep deprivation; SB: suicidal behaviours; SI: suicidal ideation; SP: suicidal plans; SA: suicide attempts; ST: suicidal thoughts; PSQI: Pittsburgh Sleep Quality Index.

\*Suicide and overall mortality rates are higher in patients with epilepsy.

\*\* Both insomnia and suicidality are recurrently seen in patients surviving to stroke; therefore, this is seen as a population at risk for suicidality.

**Table 3.** Characteristics of the studies concerning short sleep duration and suicidal behaviour in the elderly.

| Authors, Year (Country)                | Study type      | Sample  | Sleep duration   | Suicidal behaviour   | Main results  |
|--|-----------------|---|--|--|---|
| Fässberg, M. M., et al., 2013 (Sweden) | Cross-sectional | N=2777 Individuals with extreme old-age (97-year-olds) without dementia (community) | SSD: Score $\geq 4$ on the CPRS<br>Estimation of the total number of hours of sleep based on answers about sleep initiation and awakening. | Death thoughts/ suicidal feelings (SF) (during the past month; based on Paykel questions)  | Nearly 90% of the individuals with SF had sleep complaints.<br>Reduced sleep was seemed to be more frequent in those with SF, but the association was not significant.  |
| Lapierre, S., et al., 2012 (Canada)    | Cross-sectional | N=2777 $\geq 65$ years old (community)  | SSD: $< 6$ h   | Death thoughts: “wishes to die”, as defined by the question “In the last 12 months, did you have a period of at least two weeks when you thought that you would better be dead?” | Although individuals with wishes to die frequently had poor sleep quality in general (even after controlling for depression), when considering SSD separately, the increased prevalence of wishes to die was not significant. |

SSD: short sleep duration; SF: suicidal feelings; CPRS: Comprehensive Psychopathological Rating Scale.

**Table 4.** Characteristics of the studies concerning sleep circadian rhythms and suicidal behaviour in children and adolescents.

| Authors, Year (Country)              | Study type      | Sample   | Variable  | Suicidal behaviour | Main results  |
|--------------------------------------|-----------------|--|---|--------------------|---|
| Gau, S.S., et al., 2007 (China)      | Cross-sectional | N=1388 Adolescents (12-13 years old) (community) | MTC/ ETC  | SI or SA           | Adolescents with an ETC were more likely to report SI or SA than those with MTC or IC. The magnitude of the association decreased but remained significant after controlling for the tendencies to internalize or externalize problems. ETC adolescents had shorter weekday sleep time, longer weekend sleep time, more daytime napping, and greater sleep compensation on weekends, suggesting a BISD.   |
| Gangwisch, J. E., et al., 2010 (USA) | Cross-sectional | N=15659 Adolescents (community)                  | BT (asked to the subjects and to their parents separately*) | SI                 | Adolescents with PTSD of midnight or later were 20% more likely to have SI, compared to those with PSBT at 10PM or earlier. The association remained significant after controlling for demographic variables, self-perception of parents' care, and depression. Both depression and SI were associated with later PSBT, shorter sleep duration, and perception of not getting enough sleep. The inclusion of sleep duration and perception of getting enough sleep in the analysis attenuated the association, both for depression (OR= 1.07) and SI (OR=1.09), suggesting they could act as mediators. |

| Authors, Year (Country)                  | Study type  | Sample  | Variable                  | Suicidal behaviour           | Main results  |
|--|---|---|---------------------------|------------------------------|---|
| McGlinchey and Harvey, A. G., 2015 (USA) | Prospective   | N=20 745 Adolescents (community) (follow-up of 6years, until 18-26 years old) | BT (in summer holidays)** | SI and SA (in the past year) | Late BT was positively associated to SI and SA, both in a cross-sectional analysis and in the subsequent evaluations.   |
| Kim, J. H., et al., 2015 (Korea)         | Cross-sectional (using data from a retrospective study) | N=191 642 Adolescents (community)   | Time in bed, AT, and BT   | SI, SP, SA                   | SI: the risk was increased by very short time in bed (1.487-fold), early AT (1.231-fold), and early BT (1.748-fold); it was lower with very long time in bed (0.611-fold) and late AT (1.528-fold). SP: the risk increased with very short time in bed (1.744-fold), early AT (1.485-fold), and early BT (2.494-fold); it decreased with very long time in bed (0.620-fold). SA: increased risk with early AT (1.819-fold) and late BT (1.313-fold) AT and BT patterns for the association with SB were U-shaped. |
| McGlinchey, E. L., et al., 2016 (USA)    | Cross-sectional   | N=223 Adolescents with mood disorders and self-injurious behaviours           | Circadian reversal        | SA                           | After adjustment for demographic factors and self-reported depression, a reversal in circadian timing was a significant predictor of SA ( $\beta=0.18$ )  |

SB: suicidal behaviours; SI: suicidal ideation; SP: suicidal plans; SA: suicide attempts; ETC: evening-type chronotype; MTC: morning-type chronotype; IC: intermediate chronotype; BISD: behaviourally-induced sleep deprivation; PSBT: parental-set bedtimes; BT: bedtime; AT: awakening time.

\*Parental set bedtimes are less likely to be influenced by a previous mental health disorder of the adolescent, \*\* Summer bedtime was used, for representing a less restricted schedule and, thus, the natural tendency of the individual to go to sleep later or earlier.

**Table 5.** Characteristics of the studies concerning sleep circadian rhythms and suicidal behaviour in adults.

| Authors, Year (Country)           | Study type   | Sample  | Variable                   | Suicidal behaviour                  | Main results  |
|-----------------------------------|--|---|----------------------------|-------------------------------------|---|
| Chan, J.W., et al., 2014 (China)  | Cross-sectional analysis (in a longitudinal study) | N=253 Patients with depressive disorder   | MTC/ ETC                   | SA (lifetime and in the last month) | Subjects with ETC reported more SA (both in the last month and lifetime SA). ETC was also associated to non-remission of depression (3-fold risk increase), independent of insomnia severity and other psychiatric disorders.   |
| Selvi, Y., et.al., 2010 (Turkey)  | Case-control                                       | N=160 Cases: 80 patients with MD Controls: 80 healthy individuals, demographically matched. | MTC/ ETC/ neither (IC)     | SI                                  | Among MD patients, those with ETC and IC reported significantly higher scores for SI than those with MTC. Among controls, only ETC individuals differed significantly. In the MD group, after controlling for depressive symptoms, chronotype and sleep quality did not significantly predict SI. Among the models with the possible determinants of SI, the most valid one did not show a significant effect of chronotype on SI, in either group. |
| Perlis, M. L., et al., 2016 (USA) | Retrospective                                      | N=35 332 Individuals who died by suicide in 2003-2010, in the USA                           | ETC/ Nocturnal wakefulness | Death by suicide                    | When accounting for the proportion of the population likely awake at a certain time, the authors show that most suicides were committed at night, with a peak at 02:00-02:59 AM. 63.9% of the suicides occurred from 0:00 to 6:00. There is an incident rate of $10.3 \pm 4.9\%$ from 00:00-05:59, vs. $2.2 \pm 0.7\%$ in the remaining 18 hours.   |

| Authors, Year (Country)             | Study type      | Sample   | Variable  | Suicidal behaviour | Main results   |
|-------------------------------------|-----------------|--|---|--------------------|--|
| Kodaka M., et al., 2014 (Japan)     | Case-control    | N=194<br>Interviews with a close family member of:<br>Cases: 49 suicide victims<br>Controls: 145 gender, age and residence-matched living individuals of the community | Day-night reversal  | Death by suicide   | No significant association was found between day-night reversal and an increased suicide risk, although sleep disturbances in general were significantly more prevalent among suicidal individuals (OR=21.6, independently of mental disorders).   |
| Dell'Osso, L., et al., 2014 (Italy) | Cross-sectional | N=65<br>Out- and in-patients with chronic PTSD   | "Sleep" subscale in the MOODS-SR scale (rhythmicity and vegetative functions)   | SI; SA             | Increased percentages of SI were seen for about half of the sleep rhythmicity sub-domain items of the scale, but no association was found for SA. The associations were maintained after adjusting for depression.   |
| Benedetti, F., et al., 2015 (Italy) | Cross-sectional | N=87<br>Caucasian in-patients with Bipolar Disorder type I   | Genotyping of CLOCK gene rs1801260, whose *C polymorphism is associated with sleep phase delay, with evening preference | SA                 | CLOCK gene rs1801260*C carriers showed worse suicide scores. This polymorphism alone did not influence the likelihood of attempting suicide, but its presence seemed to interact with the experience of stressful events in the early life, increasing the risk of SA. The presence of the *C allele also increased the association between a positive history of SA and current SA. |

SI: suicidal ideation; SA: suicide attempts; ETC: evening-type chronotype; MTC: morning-type chronotype; IC: intermediate chronotype; MD: major depression; MOODS-SR: Mood Spectrum Self-Report, a questionnaire that explores lifetime mood spectrum phenomenology, including dysregulations in rhythmicity and vegetative functions.

## 4. Discussion

The results of this review globally suggest that short sleep time and an evening-type chronotype are associated with an increased risk of suicidal behaviours. Some factors should be taken into account when interpreting these results, and they are discussed in this section.

### 4.1. Short Sleep Duration and Suicidal Behaviour

The analysis of the included studies points to a significant association between short sleep time and the presence of suicidal behaviours, for both adults and children/adolescents. This effect seems to be dose-related, as studies that included more categories of sleep duration or even considered it as a continuous variable suggest the existence of a U-shaped [28] or inverse J-shaped [21] curve for the effect of sleep duration on suicidal behaviours, with shorter sleep time increasing the risk in an almost linear manner. There seems to be a nadir around 8-9 hours of sleep per night, depending on the population under study. Some studies suggest that above a certain number of hours of sleep (>8 hours [21], ≥9 hours [17], or ≥10 hours [41]) the risk for suicidal behaviour is also increased, although to a lesser extent than with short sleep duration or becoming non-significant after adjustment for some factors. The study conducted by Winsler et al. [28], which evaluated sleep duration continuously, further suggests that even within a range of sleep time usually considered normal, having just 1 hour less of sleep (e.g. 7 vs. 8 hours) is

associated with significantly greater odds of suicidal thoughts and behaviours, in adolescents. More studies with a continuous evaluation of sleep duration are needed to confirm this apparently dose-related association, both in adolescent and adult populations.

Weekend catch-up sleep duration is considered a better indicator of chronic sleep deprivation than sleep duration on weekdays [14, 20]. In this context, the studies conducted by Kang et al. [14] and Lee et al. [20] are important for demonstrating that a chronic, behaviourally-induced sleep restriction can increase the risk of suicide in adolescents, independently of the presence of sleep disturbances such as insomnia, which could be a symptom of previous mental health disorders. Thereby, these studies suggest that short sleep could be an independent risk factor for suicidal behaviour. However, more studies are needed to confirm this hypothesis.

For the elderly population, the studies did not show any significant effect of short sleep duration over the presence of suicidal behaviours [6, 45]. These non-significant results may be explained by a natural tendency of many individuals for sleeping a smaller number of hours as they age [6]. More studies should also address this population.

Several possible mechanisms have been proposed to explain the apparent association between short sleep duration and suicidal behaviours.

One of those mechanisms implicates the psychological effects of short sleep duration. Short sleep seems to have deleterious effects on cognition and behaviour. Namely, it

causes an impairment on the individual's problem-solving and decision-making abilities, judgement, concentration, emotional regulation, and impulse control, thereby promoting states of anxiety, hostility/aggressiveness, frustration, catastrophic thinking, hopelessness, depressed mood and rumination [9, 15, 17, 21, 26, 33, 34, 38]. These factors are all considered to influence the development of suicidal behaviours. Kohyama [16] also suggests that an inadequate sleep hygiene in the early stages of life leads to low self-esteem and behavioural problems, including suicide, in adulthood. The main question raised by these theories is whether the effects are mediated by the development of a depressive disorder, which is perhaps the main risk factor for suicide [1].

These psychological effects are corroborated in a qualitative study recently conducted by Littlewood et al. [50]. In their study, suicide attempters identified sleep duration as one of the factors influencing the development of suicidal behaviours. Most individuals reported that they were not achieving a 'good sleep' when having suicidal feelings. On one hand, not getting enough sleep at night was seen as an aggravating factor for the individuals' condition, by increasing feelings of frustration, irritability and anger, worsening relationships with others and thus reducing social support. Moreover, not getting enough sleep reduced their mental strength and cognitive resources, as well as their ability to control thoughts, focus and process information; individuals became less active and fell into negative thoughts. On the other hand, sleep was commonly seen as an escape from a negative reality, allowing a break in rumination and negative thinking, acting as a relief factor for the individuals' mental state. A resetting function was also attributed to sleep, allowing a better attitude towards the individuals' challenges in the next day.

The psychological alterations could be explained by some neurobiological mechanisms. The neural basis for the association between sleep loss and suicidal behaviours has not been fully established yet, but there seems to be a role of serotonin, oxytocin and the prefrontal cortex [16].

Individuals who attempted suicide seem to have reduced serotonin synthesis in their prefrontal cortex [51]. Serotonergic activity is highest during wakefulness, being activated by factors such as exposure to morning light, physical affection, and rhythmic movements such as walking, chewing, or even regular breathing movements [1, 16]. It is likely that an individual with chronic short sleep, feeling tired and sleepy, will perform less rhythmic activity, leading to less stimulation of the serotonergic system. This could lead to suicidal behaviour, dependent or independently from depression [1]. Low serotonin levels impair the ability to consider long-term rewards and consequences, thus explaining not only hopelessness but also a greater impulsivity and poor management of negative emotions, that could lead to suicide [1, 11, 37].

Sleep disturbances could cause neural changes, such as an impairment on synaptic restoration, a reduction in white matter integrity, and possible damage to the hippocampus and

frontal cortex [16]. Sleep loss seems to decrease the activity in the frontoparietal attention network, leading to decreased decision-making and self-control abilities [52].

Although sleep deprivation has been indicated for the treatment of depression, this effect has been justified by an acute action, opposite to the effect of chronic sleep deprivation, which seems to increase the risk for depression and suicide [1, 9]. However, this apparently beneficial acute effect may not always be applicable, as a case-report [53] mentions a suicidal attempt after an acute 72h sleep deprivation, in a previously healthy individual. More studies should be conducted to evaluate whether this effect is real.

#### **4.2. Sleep Circadian Rhythms and Suicidal Behaviours**

Although the number of studies across the literature is small to allow clear conclusions, their analysis suggests that an evening-type chronotype could be associated with a greater risk of developing suicidal behaviours. The results were slightly more consensual for adolescents than for adults. In this last group, the studies that found a significant relation were conducted in individuals with psychiatric disorders (depression [48], post-traumatic stress disorder [49], bipolar disorder [47]) or in suicide victims [3], whereas both studies with a non-significant association were case-control studies comparing suicide victims with controls [10] or patients with major depression and controls [24].

For children and adolescents, Kim et al.'s results [2] are somewhat divergent from the remaining studies, as they suggest that the association of awakening and bedtime patterns with suicidal behaviours seems to be U-shaped, i.e., greater for both earlier and later wake-up times and bedtimes, than for a certain hour considered to be adequate. For wake-up time, once the authors use 7 hours of sleep per night for comparison, the U-shaped effect could be related to sleep duration (short vs. long) instead of the chronotype itself. In the particular case of suicide attempts, however, only late bedtimes were a risk factor. In the other studies, it seems consensual that the risk of suicidal behaviour increases with an evening-type chronotype.

It is conceivable that a possible effect of circadian rhythm alterations on the risk for suicidal behaviour would be driven by a behaviourally-induced sleep deprivation, due to the interaction between an evening-type chronotype and a lifestyle that demands early morning awakening. More studies are necessary to explore this hypothesis. However, some mechanisms suggested to explain this association overlap the ones suggested for short sleep duration – late bedtimes seem to promote inattention, aggressive behaviours, social problems, stress and feelings of hopelessness [2, 24]. This overlap of mechanisms could support this hypothesis. If the association is mediated by a shorter sleep duration, some studies may have not shown it because there was a later awakening time allowing an adequate sleep duration (some of the studies did not assess wake-up times), or because these individuals are biologically shorter sleepers.

Some authors suggest that the simple fact of being awake at night promotes rumination and intensifies feelings of

hopelessness, loneliness and distress, aggravated by both the inability to sleep, and the sense of isolation associated with a decreased social support at night (friends and relatives are most likely asleep) [3, 46, 50]. Additionally, in the qualitative study conducted by Littlewood *et al.* [50], suicide attempters refer that being awake during the biological night made them more prone to focus on negative thoughts (fewer distractions from the outside world), leading to introspectiveness, rumination, and negative self-appraisal.

Perlis *et al.* [9] constructed an integrating conceptual model suggesting that the effect of being awake at night could be mediated by an hypoactivation of the frontal lobes, with a possible role of the HPA axis as a response to life stressors. This hypofrontality, along with a decreased social support and substance abuse, would lead to reduced problem-solving abilities and a more impulsive behaviour, which could explain suicidal behaviour.

Individuals with a sleep-phase delay (evening-type chronotype) have a decreased exposure to morning light, an activator of the serotonergic system – therefore, reduced serotonin levels could explain the higher risk for suicide [1, 2, 16]. Also, poor sleep circadian habits seem to interact with other factors to decrease serotonergic activity (e.g. staying at home all day, digital media use, bad posture, tendency for depression or losing self-control) [16].

Genetic factors have also been suggested, such as alterations in the CLOCK genes regulating sleep circadian rhythms. In this context, Benedetti *et al.* [47] showed that the CLOCK gene rs181260\*C polymorphism conditioned not only sleep phase delays, but also an increased risk for suicide attempts (most likely interacting with a previous experience of stressful events, making the individuals more sensitive to it). If this gene is involved in the presence of a sleep phase delay and also somehow influences the development of suicidal behaviours, these disorders could be connected. Two mechanisms were proposed by the authors: 1) the clock gene machinery could control circadian gene expression and responsivity to stimuli at cellular level, modulating the activity of brain structures that control emotions and behaviour; 2) rs1801260\*C genotype is associated to sleep phase delay and insomnia, which are in turn associated with suicide in the general population – thus, the effect on sleep delay could mediate the influence of this gene on depression and suicide.

#### 4.3. Final Considerations

In many of the studies mentioned across this review, the authors point out the importance of these associations for suicide prevention. In fact, keeping favourable sleep and circadian habits increases serotonergic system activity and could therefore prevent suicidal behaviour [1]. This is particularly important at early ages, to allow the correct development of protective factors such as long-term reward seeking, synaptic homeostasis, and a satisfying social life, which contribute to a better mental health, with less problematic behaviours later in life [16]. An improvement of sleep circadian rhythm disturbances, especially through an

early intervention in children, could strengthen self-esteem and reduce their suicide risk in adulthood [11, 16].

Kohyama [11] mentions that the solution for most of the sleep and circadian rhythm disturbances comes through a good sleep hygiene, by going to sleep earlier and assuring an adequate number of hours of sleep per night. Morningness may be associated to a higher-order personality, more stability, better lifestyle patterns in general, social and motivational advantages, with less reports of aggressive behaviours, stress or hopelessness. [24]. Therefore, those seem to be important ways to prevent suicide.

The use of sedative/hypnotic medication seems to be, at first sight, the easier solution for sleep issues. However, it is important to guarantee that it actually improves daytime dysfunction, which is one of the greatest issues in people with sleep disorders and appears to contribute to suicidal behaviour. Once about 40% of the individuals under sleep medication still experience daytime dysfunction [6], it is important to assess this effect and, if necessary, find alternatives to treat sleep disturbances while improving the individuals' performance on its daily activities. Plus, especially in the case of a behaviourally-induced alteration in circadian rhythms or sleep duration, it is important to evaluate whether a pharmacological treatment is actually necessary. Counselling about sleep hygiene or psychotherapy might be more beneficial and easier ways to improve the individual's sleep quality and general mental health.

This review has limitations. The search was restricted to publications in the last 10 years, thus possibly excluding some important previous studies. Furthermore, some of the studies included were conducted with psychiatric patients, so some of the differences found could be partially related to the individual's mental disorder.

Many factors could be influencing the results of the studies included in this review, biasing them in one direction or the other. The main limitations pointed by the authors were a lack of objective measures for sleep duration (the assessment is based on self-report, thus being possibly subjected to biases) and a cross-sectional analysis in most of the existent studies.

Once the vast majority of the studies on this matter are cross-sectional, the main problem raised by the interpretation of the results is the direction of the causality between a chronic short sleep duration or an evening-type chronotype and the presence of suicidal behaviours. Sleep disturbances are common symptoms of psychiatric disorders [38], so it becomes difficult to determine if short sleep is the cause or the consequence of those disorders. However, the association found between behaviourally-induced sleep deprivation and suicidal behaviours [14, 20] points to the first option, as that type of sleep deprivation seems to depend on the individuals' lifestyle and not on a subjacent psychiatric disorder. Prospective studies, which are scarce in this area, would be helpful in determining the direction of causality, and should therefore be encouraged.

Another controversial point about these associations is their dependence, or not, on the effect of depression. Some of the studies tried to approach this matter (e.g. [7, 15, 17, 35, 44]),

but the results are not consensual. This controversy highlights the need for more studies, preferably prospective, with objective measures of sleep duration, depression and suicidal behaviours.

Another factor making it difficult to interpret and compare the results is the variability between studies when it comes to the definition of short sleep, varying from <4 hours to <8 hours (e.g. [18, 29-31]), or even being in the same category as long sleep duration [41]. Furthermore, the number of categories of sleep duration considered in the analyses varied from 2 to 7, and some studies considered sleep duration as a continuous variable [28, 54, 55]. It would be tempting to compare the studies using the objective sleep duration in hours, and not categories, but the biological and cultural differences in the definition of short sleep should also be taken into account. Some populations are naturally more prone to sleep a smaller number of hours, so in culturally sleep deprived countries the authors could tend to consider lower values of sleep duration as normal.

Finally, another main limitation in this area is that experimental studies are hardly ethical, so an important line of investigation on the direction of causality is lost. A possible way of bypassing this limitation is the development of more prospective studies, as the determination of a temporal relation could help define the direction of causality.

In spite of these limitations, this review allows a good description of the state-of-the-art concerning the possible effect of both short sleep duration and circadian rhythms on suicidal behaviours, highlighting some important research areas. Another important strength is the description of these associations for every age stage and the inclusion of any type of suicidal behaviour. This can be important in developing adequate strategies to prevent suicidal behaviours in all ages. The inclusion of articles written in four languages is another strength, as it reduces the risk of publication bias.

## 5. Conclusions

This review suggests a significant association between short sleep duration and suicidal behaviours, which seems to be dose-related. Namely, a behaviourally-induced sleep deprivation seems to be a risk factor for those behaviours. The results also point to an association of an evening-type chronotype with suicidal behaviours. Some important aspects need to be addressed in future research to further clarify these associations, enabling the development of interventions to reduce suicide risk.

## Authors Contributions

T. P. has contributed by researching the data, analysing and interpreting the data and drafting the manuscript. T. P., S. M. and L. F. contributed by designing the study, analysing and interpreting the data, and critically revising the manuscript. All authors gave final approval of the version to be published.

## References

- [1] Kohyama, J., *Sleep, serotonin, and suicide in Japan*. J Physiol Anthropol, 2011. 30(1): p. 1-8.
- [2] Kim, J. H., et al., *Associations between time in bed and suicidal thoughts, plans and attempts in Korean adolescents*. BMJ Open, 2015. 5(9): p. e 008766.
- [3] Perlis, M. L., et al., *Nocturnal Wakefulness as a Previously Unrecognized Risk Factor for Suicide*. J Clin Psychiatry, 2016. 77(6): p. e 726-33.
- [4] WHO, *World health statistics 2016: monitoring health for the SDGs, sustainable development goals*. 2016. p. 62, 63.
- [5] Fitzgerald, C. T., E. Messias, and D. J. Buysse, *Teen sleep and suicidality: results from the youth risk behavior surveys of 2007 and 2009*. J Clin Sleep Med, 2011. 7(4): p. 351-6.
- [6] Lapierre, S., et al., *Daily hassles, physical illness, and sleep problems in older adults with wishes to die*. Int Psychogeriatr, 2012. 24(2): p. 243-52.
- [7] Gelaye, B., et al., *Association of poor subjective sleep quality with suicidal ideation among pregnant Peruvian women*. Gen Hosp Psychiatry, 2015. 37(5): p. 441-7.
- [8] Hor, K. and M. Taylor, *Suicide and schizophrenia: a systematic review of rates and risk factors*. J Psychopharmacol, 2010. 24(4 Suppl): p. 81-90.
- [9] Perlis, M. L., et al., *Suicide and sleep: Is it a bad thing to be awake when reason sleeps?* Sleep Med Rev, 2016. 29: p. 101-7.
- [10] Kodaka, M., et al., *Suicide risk among individuals with sleep disturbances in Japan: a case-control psychological autopsy study*. Sleep Med, 2014. 15(4): p. 430-5.
- [11] Kohyama, J., *The possible long-term effects of early-life circadian rhythm disturbance on social behavior*. Expert Rev Neurother, 2014. 14(7): p. 745-55.
- [12] Bernert, R. A. and T. E. Joiner, *Sleep disturbances and suicide risk: A review of the literature*. Neuropsychiatr Dis Treat, 2007. 3(6): p. 735-43.
- [13] Stubbs, B., et al., *A population study of the association between sleep disturbance and suicidal behaviour in people with mental illness*. J Psychiatr Res, 2016. 82: p. 149-54.
- [14] Kang, S. G., et al., *Weekend catch-up sleep is independently associated with suicide attempts and self-injury in Korean adolescents*. Compr Psychiatry, 2014. 55(2): p. 319-25.
- [15] Ferentinos, P., et al., *Sleep disturbance as a proximal predictor of suicidal intent in recently hospitalized attempters*. Sleep Med, 2016. 19: p. 1-7.
- [16] Kohyama, J., *Neural Basis of Brain Dysfunction Produced by Early Sleep Problems*. Brain Sci, 2016. 6(1).
- [17] Lee, M. S., et al., *The association between mental health, chronic disease and sleep duration in Koreans: a cross-sectional study*. BMC Public Health, 2015. 15: p. 1200.
- [18] Blasco-Fontecilla, H., et al., *Short self-reported sleep duration and suicidal behavior: a cross-sectional study*. J Affect Disord, 2011. 133(1-2): p. 239-46.

- [19] Yen, C. F., B. H. King, and T. C. Tang, *The association between short and long nocturnal sleep durations and risky behaviours and the moderating factors in Taiwanese adolescents*. Psychiatry Res, 2010. 179(1): p. 69-74.
- [20] Lee, Y. J., et al., *Insufficient sleep and suicidality in adolescents*. Sleep, 2012. 35(4): p. 455-60.
- [21] Gunnell, D., et al., *Sleep and suicide: an analysis of a cohort of 394,000 Taiwanese adults*. Soc Psychiatry Psychiatr Epidemiol, 2013. 48(9): p. 1457-65.
- [22] Gau, S. S., et al., *Association between morningness-eveningness and behavioral/emotional problems among adolescents*. J Biol Rhythms, 2007. 22(3): p. 268-74.
- [23] Oliveira-Ferreira, M., *[Circadian rhythms: what role in psychiatric disorders?]*. 2011, Faculty of Medicine, University of Porto.
- [24] Selvi, Y., et al., *Associations between chronotype, sleep quality, suicidality, and depressive symptoms in patients with major depression and healthy controls*. Chronobiol Int, 2010. 27(9-10): p. 1813-28.
- [25] McGlinchey, E. L., et al., *The Role of Sleep Disturbance in Suicidal and Nonsuicidal Self-Injurious Behavior among Adolescents*. Suicide Life Threat Behav, 2016.
- [26] Gangwisch, J. E., et al., *Earlier parental set bedtimes as a protective factor against depression and suicidal ideation*. Sleep, 2010. 33(1): p. 97-106.
- [27] Giannotti, F., et al., *Circadian preference, sleep and daytime behaviour in adolescence*. J Sleep Res, 2002. 11(3): p. 191-9.
- [28] Winsler, A., et al., *Sleepless in Fairfax: the difference one more hour of sleep can make for teen hopelessness, suicidal ideation, and substance use*. J Youth Adolesc, 2015. 44(2): p. 362-78.
- [29] An, H., J. H. Ahn, and S. Y. Bhang, *The association of psychosocial and familial factors with adolescent suicidal ideation: A population-based study*. Psychiatry Res, 2010. 177(3): p. 318-22.
- [30] McKnight-Eily, L. R., et al., *Relationships between hours of sleep and health-risk behaviors in US adolescent students*. Prev Med, 2011. 53(4-5): p. 271-3.
- [31] Park, J. H., J. H. Yoo, and S. H. Kim, *Associations between non-restorative sleep, short sleep duration and suicidality: findings from a representative sample of Korean adolescents*. Psychiatry Clin Neurosci, 2013. 67(1): p. 28-34.
- [32] Matamura, M., et al., *Associations between sleep habits and mental health status and suicidality in a longitudinal survey of monozygotic twin adolescents*. J Sleep Res, 2014. 23(3): p. 290-4.
- [33] Koyawala, N., et al., *Sleep problems and suicide attempts among adolescents: a case-control study*. Behav Sleep Med, 2015. 13(4): p. 285-95.
- [34] Chakravorty, S., et al., *Suicidal ideation in veterans misusing alcohol: relationships with insomnia symptoms and sleep duration*. Addict Behav, 2014. 39(2): p. 399-405.
- [35] Krakow, B., et al., *Sleep disturbances and suicidal ideation in sleep medical center patients*. J Affect Disord, 2011. 131(1-3): p. 422-7.
- [36] Pigeon, W. R., J. A. Woosley, and K. L. Lichstein, *Insomnia and hypnotic medications are associated with suicidal ideation in a community population*. Arch Suicide Res, 2014. 18(2): p. 170-80.
- [37] Tang, W. K., et al., *Is insomnia associated with suicidality in stroke?* Arch Phys Med Rehabil, 2011. 92(12): p. 2025-7.
- [38] Weis, D., et al., *The Effect of Sleep Problems on Suicidal Risk among Young Adults in the Presence of Depressive Symptoms and Cognitive Processes*. Arch Suicide Res, 2015. 19(3): p. 321-34.
- [39] Wigg, C. M., A. Filgueiras, and M. Gomes Mda, *The relationship between sleep quality, depression, and anxiety in patients with epilepsy and suicidal ideation*. Arq Neuropsiquiatr, 2014. 72(5): p. 344-8.
- [40] Luxton, D. D., et al., *Prevalence and impact of short sleep duration in redeployed OIF soldiers*. Sleep, 2011. 34(9): p. 1189-95.
- [41] Bae, S. M., et al., *Risk factors for suicidal ideation of the general population*. J Korean Med Sci, 2013. 28(4): p. 602-7.
- [42] An, K. O., J. Y. Jang, and J. Kim, *Sedentary Behavior and Sleep Duration Are Associated with Both Stress Symptoms and Suicidal Thoughts in Korean Adults*. Tohoku J Exp Med, 2015. 237(4): p. 279-86.
- [43] Goodwin, R. D. and A. Marusic, *Association between short sleep and suicidal ideation and suicide attempt among adults in the general population*. Sleep, 2008. 31(8): p. 1097-101.
- [44] Chin, Y. R., H. Y. Lee, and E. S. So, *Suicidal ideation and associated factors by sex in Korean adults: a population-based cross-sectional survey*. Int J Public Health, 2011. 56(4): p. 429-39.
- [45] Fassberg, M. M., et al., *Suicidal feelings in the twilight of life: a cross-sectional population-based study of 97-year-olds*. BMJ Open, 2013. 3(2).
- [46] McGlinchey, E. L. and A. G. Harvey, *Risk behaviors and negative health outcomes for adolescents with late bedtimes*. J Youth Adolesc, 2015. 44(2): p. 478-88.
- [47] Benedetti, F., et al., *Effects of CLOCK gene variants and early stress on hopelessness and suicide in bipolar depression*. Chronobiol Int, 2015. 32(8): p. 1156-61.
- [48] Chan, J. W., et al., *Eveningness and insomnia: independent risk factors of nonremission in major depressive disorder*. Sleep, 2014. 37(5): p. 911-7.
- [49] Dell'Oso, L., et al., *Alterations in circadian/seasonal rhythms and vegetative functions are related to suicidality in DSM-5 PTSD*. BMC Psychiatry, 2014. 14: p. 352.
- [50] Littlewood, D. L., et al., *Understanding the role of sleep in suicide risk: qualitative interview study*. BMJ Open, 2016. 6(8): p. e 012113.
- [51] Leyton, M., et al., *alpha-[11C] Methyl-L-tryptophan trapping in the orbital and ventral medial prefrontal cortex of suicide attempters*. Eur Neuropsychopharmacol, 2006. 16(3): p. 220-3.
- [52] Ma, N., et al., *How acute total sleep loss affects the attending brain: a meta-analysis of neuroimaging studies*. Sleep, 2015. 38(2): p. 233-40.
- [53] Szpak, A. and D. Allen, *A case of acute suicidality following excessive caffeine intake*. J Psychopharmacol, 2012. 26(11): p. 1502-10.



- [54] Arnold, E. M., et al., *Sleep Problems, Suicidality and Depression among American Indian Youth*. J Sleep Disord Treat Care, 2013. 2(3): p. 119.
- [55] Sarchiapone, M., et al., *Hours of sleep in adolescents and its association with anxiety, emotional concerns, and suicidal ideation*. Sleep Med, 2014. 15(2): p. 248-54.